Procedures for Estimating Depletion

in the

Lower Bear River Basin in Idaho

Submitted to PacifiCorp

by

Robert W. Hill, P.E., Ph.D.
Logan, Utah

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I. Introduction

Depletion of water by agricultural and other uses forms the basis for water rights accounting within the Bear River Basin (Amended Bear River Compact). Hydrologic realities on the Bear River below Bear Lake mandate that a careful accounting be made of any and all appropriated waters. Thus, depletions must be determined for any new applications to appropriate in order to fulfill the accounting requirements.

Depletions for agricultural crop water use were calculated based on the "Bear River Commission Approved Procedure." Depletions for municipal and dairy water use were derived from consideration of current practices and comparison with actual use patterns in Cache Valley and elsewhere. Procedures for developing depletion estimates for Bear Lake, Caribou and Franklin Counties of Idaho areas in the Bear River Basin are included herein.

II. Estimation of Agricultural Water Depletions

II.A. Crops

Agricultural crop depletion is calculated as the water year evapotranspiration less the sum of carryover soil moisture and effective precipitation. Estimated depletion, which accounts for the effect of winter and summer precipitation and evapotranspiration, thus represents a net irrigation requirement at 100 percent irrigation efficiency. In equation form:

$$Dpl = E_t - SM_{co} - Pef \qquad (1)$$

where Dpl is estimated depletion; E_t is calculated cropwater use from one of the calibrated empirical E_t equations; SM_{co} is moisture which is "carried over" from the previous non-growing season (Oct 1 - April 30) as stored soil water in the root zone available for cropwater use subsequent to May 1; and, Pef is an estimate of that portion of precipitation during May - September which could be used by crops. See the Appendix for additional details.

Average crop water use, growing and non-growing season precipitation and depletion for various crops are shown in Tables 1, 2 and 3 for Bear Lake, Caribou, and Franklin Counties, respectively. Sprinkle irrigation depletions are adjusted for wind drift evaporation loss from water droplets in the air for mild to moderate wind conditions. This was added to the ET minus effective rainfall (net irrigation requirement) to estimate depletion as shown in Tables 1, 2 and 3.

Table 1. Estimated Water Year Depletion for BEAR LAKE County, for the period 1972-1996 using the NWS Station at LIFTON. Elevation 5926 ft., Latitude 42.12 deg N

Crop	Root Depth	Crop Water Use, Et	Carry Over SM	Growing Season Eff ppt	Depletion Surface Irrigation		Depletion Sprinkle Irrigation	
	ft	in	in	in	inch	AF/ac	inch	AF/ac
ALFALFA	4.5	26.9	3.7	4.6	18.7	1.56	20.9	1.74
PASTURE	2.3	21.6	2.4	5.0	14.2	1.18	15.9	1.33
OTHER HAY	2.3	23.3	2.5	4.3	16.5	1.38	18.5	1.54
SP GRAIN	3.1	20.2	3.4	3.6	13.2	1.10	14.8	1.23
ORCHARD	3.6	26.1	3.5	4.4	18.3	1.52	20.5	1.70
TURF	1.0	19.2	1.1	5.1	13.0	1.08	14.9	1.25
GARDEN	2.0	15.2	2.2	4.1	8.9	0.74	10.2	0.85

All values are 25 year averages. Effective precipitation is 80 percent of total during growing season. Carry over soil water is 67 percent of winter precipitation adjusted for usable soil water for a FSndy Loam (water holding capacity of 1.5 in/ft). Sprinkler depletion adjusted for wind drift evaporation loss of delivered irrigation water (8% fields, 10% turf & garden).
Average precipitation: Oct-Apr 6.04, May-Sep 5.46, Total 11.50

Example crop water use depletion:

Example II.A.1. The application is for groundwater to irrigate 200 acres in Caribou County.

Assuming sprinkle irrigated alfalfa, the depletion, from Table 2, is 19.1 inches or 1.59 ac ft./acre. The total depletion for the 200 acres in this application is 318 ac ft. (318 = 200 x 1.59).

The estimated diversion requirement, assuming 65% irrigation efficiency is 437 ac ft. (437 = 318/(1.12 x 0.65)). The factor 1.12 accounts for the eight percent of the delivered field water lost to wind drift and evaporation as used in calculating sprinkled crop depletion in Tables 1, 2, or 3. A factor of 1.15 should be used in a similar manner with depletion of turf and garden to calculate diversions.

Example II.A.2. Replacement depletion is required to mitigate 160 ac ft. of depletion from a domestic subdivision development in Bear Lake County. The developer has 80 acres of surface irrigated pasture that he is willing to dry up. How many additional acres of surface irrigated meadow hay ("other hay" in Tables 1, 2 and 3) must also be purchased and dried up?

The depletion from 80 acres of surface irrigated pasture is 1.18 ac ft./acre (Table 1.). Thus 94.4 ac ft. (94.4 = 80 x 1.18) is contributed to the mitigation depletion from the pasture. The balance of 65.6 ac ft. (65.6 = 160 - 94.4) needs to come from other hay. This can be provided by drying up at least 47.5 acres (47.5 = 65.6/1.38) of other hay. This assumes both the pasture and the other hay to be fully irrigated from surface irrigation sources with no contribution from a high water table.

Table 2. Estimated Water Year Depletion for CARIBOU County, for the period 1972-1996 using the NWS Station at GRACE. Elevation 5550 ft., Latitude 42.58 deg N

Crop	Root Depth	Crop Water Use, Et	Carry Over SM	Growing Season Eff ppt	Depletion Surface Irrigation		Depletion Sprinkle Irrigation	
	ft	in	in	in	inch	AF/ac	inch	AF/ac
ALFALFA	4.0	27.3	4.2	6.0	17.1	1.42	19.1	1.59
PASTURE	2.0	21.3	2.2	5.9	13.2	1.10	14.8	1.23
OTHER HAY	2.0	23.8	2.2	5.7	15.9	1.32	17.8	1.48
SP GRAIN	2.8	19.9	3.1	4.7	12.1	1.01	13.6	1.13
CORN	3.2	16.5	3.5	5.5	7.5	0.62	8.4	0.70
POTATOES	2.0	17.7	2.2	5.4	10.1	0.84	11.3	0.94
TURF	1.0	18.5	1.1	5.8	11.6	0.97	13.4	1.11
GARDEN	2.0	14.9	2.2	5.2	7.5	0.62	8.6	0.71

All values are 25 year averages. Effective precipitation is 80 percent of total during growing season. Carry over soil water is 67 percent of winter precipitation adjusted for usable soil water for a FSndy Loam (water holding capacity of 1.5 in/ft). Sprinkler depletion adjusted for wind drift evaporation loss of delivered irrigation water (8% fields, 10% turf & garden).
Average precipitation: Oct-Apr 8.89, May-Sep 6.92, Total 15.82

Table 3. Estimated Water Year Depletion for FRANKLIN County, for the period 1976-1996 using the NWS Station at PRESTON. Elevation 4820 ft., Latitude 42.13 deg N

Crop	Root Depth	Crop Water Use, Et	Carry Over SM	Growing Season Eff ppt	Depletion Surface Irrigation		Depletion Sprinkle Irrigation	
	ft	in	in	in	inch	AF/ac	inch	AF/ac
ALFALFA	4.5	28.8	4.7	6.3	17.7	1.48	19.9	1.65
PASTURE	2.3	23.1	2.5	6.8	13.8	1.15	15.5	1.29
OTHER HAY	2.3	22.7	2.5	5.9	14.4	1.20	16.1	1.34
SP GRAIN	3.1	20.7	3.5	4.8	12.4	1.04	13.9	1.16
CORN	3.6	18.5	4.0	5.7	8.8	0.73	9.8	0.82
TURF	1.0	20.8	1.1	7.1	12.5	1.04	14.4	1.20
GARDEN	2.0	16.6	2.2	5.4	8.9	0.74	10.3	0.86

All values are 21 year averages. Effective precipitation is 80 percent of total during growing season. Carry over soil water is 67 percent of winter precipitation adjusted for usable soil water for a FSndy Loam (water holding capacity of 1.5 in/ft). Sprinkler depletion adjusted for wind drift evaporation loss of delivered irrigation water (8% fields, 10% turf & garden).
Average precipitation: Oct-Apr 10.11, May-Sep 7.26, Total 17.37

II.B. Dairy

Depletion associated with a dairy operation includes water in milk sold, evaporation of wash and flush water and evaporation of water in animal wastes. For a herd on pasture, or with solid waste composting, or in a confined situation with total waste containment and lagoon treatment the depletion would essentially be 100 percent of the supply water. However, with a slurry manure handling operation and land application, ten percent return flow may occur (which is assumed herein). In either case the supply water right should be of a sufficient quantity to satisfy the requirements in peak use months of July and August. The supply and depletion estimates for a typical 100 lactating cow dairy herd plus dry cows and replacement heifers are given in Table 4.

Example dairy depletion:

Example II.B.1. The application is for a 130 lactating cow dairy in Franklin County.

Assuming the same proportion of dry cows and replacement heifers as used in Table 4 (See Appendix Table 7.) and that slurry manure handling is used for waste material, the estimated annual depletion is 7.4 ac ft. [7.4 = (130/100) 5.71].

Table 4. Average Daily Dairy Water Supply and Depletion (Assuming Slurry Waste Handling with Land Application)

Type	Supply: Gallons Per Day	Supply: Ac ft. Per Year	Depletion: Gallons Per Day	Depletion: Ac ft. Per Year
Typical 100 Cow Herd[a]	5590	6.26	5100	5.71
Lactating Cows	35	0.0392	32.2[b]	0.0361
Wash and Flush Water (per lactating cow)	8	0.0090	7.2	0.0081
Dry Cows	17.5	0.0196	15.8	0.0176
Replacement Heifers	10	0.0112	9	0.0101
Young Heifers	3.5	0.0039	3.2	0.0035

[a]Includes 100 lactating cows, 22 dry cows, 74 replacement heifers and 37 young heifers for a total of 233 animals. See Appendix Table 7.
[b]Depletion includes water in milk plus 90% of remainder of culinary supply, thus 32.2 = 0.9(35 - 6.9) + 6.9; (6.9 gallons per day in milk export).

II.C. Livestock

Depletions for livestock (other than dairies) are determined from the supply requirements shown in Table 5 (taken from IDWR) assuming 100 percent depletion of any drinking water provided for the animals. If the animals were confined with slurry manure handling and land application, then ten percent return flow could be assumed and the depletion would be 90% of the supply.

Example livestock depletion:

Example II.C.1. Application is for stockwater of 800 head of beef cattle for June - September.

The depletion is all of the average daily supply of 12 gallons/head per day (Table 5), for the number of days of use. Thus the depletion is 3.6 ac ft. [3.6 = 800 head x 12 gallons/head x 122 days/(325,850 gal/ac ft.)].

Table 5. Average Daily Water Supply for Livestock (adapted from Appendix IV, Idaho Water Law Handbook, IDWR)

Type	Gallons per day
Cattle (other than dairy)	12
Horse	12
Mule	12
Hog	4
Goat	2
Sheep	2
Chickens (per 100)	5-10
Turkeys (per 100)	10-18

III. Estimation of Municipal and Domestic Supply and Depletion

The municipal and domestic supply and depletion amounts used in this section are volumetric rather than system capacity (design diversion rate) values. System capacity diversion rates should be obtained from IDWR publications. The examples in this section include details to illustrate the calculations. A simplification using depletion for "standardized lots" is described in the Appendix section "Depletion for Municipal and Industrial".

III.A. Municipal - Culinary

Depletion from culinary (domestic) water connections is estimated assuming an annual average of five percent loss ("indoors") of the total gallons/day per connection plus waste water disposal depletion plus irrigation depletion. Additional depletion would also accrue from stock watering (if any) out of the culinary water supply. Thus, in equation form:

$$\text{Municipal Depletion} = \text{Culinary Depletion} + \text{Waste Water Depletion} + \text{Irrigation Depletion} + \text{Other (if any)} \tag{2}$$

Actual supply volumes for culinary use (excluding irrigation) vary with season, location and number of people per connection. An estimated supply of 400 gallons/day per connection is used herein.

The estimated municipal irrigation depletion (ac ft.) from the culinary supply is equal to the irrigated area in acres multiplied by the quantity, in acre feet per acre, of the crop mix depletion (turf and garden). In equation form:

$$\text{Irrigation depletion} = \text{acres} \times \text{weighted crop depletion} \qquad (3)$$

where weighted crop depletion is the depletion for the weighted crop mix (say, 60 percent turf and 40 percent garden) obtained from Tables 1, 2 or 3.

Example Municipal - Culinary Water Depletion

Example III.A.1. The application is for a well in a community in Franklin County comprised of 150 residences with an average lot size of 0.33 acre. The average house (includes driveway and sidewalks, etc.) has a footprint of 2500 square feet. The balance of the lot is in lawn (60%) and garden (40%). Sprinkler irrigation is used (from the culinary supply) and there are no significant stock watering uses. The waste water treatment is a lagoon system constructed on previously unirrigated ground with approximately 70% of the feed water discharged at the outlet after accounting for precipitation.

Assuming that historical metered culinary water supply records are not available, use 400 gallons/day per connection for the indoor supply with a depletion of five percent (or 20 gallons per day).

a. The annual indoor annual depletion is 3.4 ac ft. (3.4 = 150 x 20 x 365/325,850).

b. The irrigation depletion is estimated from the estimated irrigated area and the weighted average turf and garden depletion from Table 3.

Irrigated area = 150(14,520 - 2500)/43,560 = 41.4 acres.
Weighted turf and garden depletion = (0.6 x 1.20) + (0.4 x .86) = 1.064 ac ft./acre.
Thus, the irrigation depletion = 41.4 x 1.064 = 44.1 ac ft.

c. The waste water depletion, as indicated above, is estimated to be 30% of the waste water treatment supply. Thus, the waste water depletion = 150 (400-20)(0.3)365/325,850 = 19.2 ac ft.

d. The sum of a, b and c is total municipal depletion which is 66.7 ac ft. (66.7 = 3.4 + 44.1 + 19.2).

Example III.A.2. The community in example III.A.1 wishes to procure the replacement depletion from a surface irrigated pasture. How many acres of pasture must be taken out of production (dried up)?

Assuming an adequately watered surface irrigated pasture, the depletion is 1.15 ac ft./acre (Table 3). The irrigated area corresponding to a depletion of 66.7 ac ft. is 58 acres (58 = 66.7/1.15).

III.B. Domestic - Subdivision

Depletions are estimated similar to those of Municipal - Culinary (Equations 2 and 3). However, larger areas of turf or pasture may be included in addition to that immediately adjacent to homes.

Example Domestic Subdivision

Example III.B.1. Application is in Franklin County for a proposed subdivision of 20 single family homes each on a 0.5 acre lot.

Average home footprint estimated to be 3,000 square feet, with 0.1 acre garden and 0.2 acre lawn. The balance of lot area will be in pasture. All irrigated with sprinkler. The land was previously not irrigated. A septic system with drain fields will be used for waste water disposal.

a. Culinary supply is 400 gallons per day per residence. The depletion, per home, with five percent indoor depletion is 20 gallons per day. The annual estimated indoor culinary depletion for 20 homes is 0.45 ac ft. (0.45 = 20 x 20 x 365/325,850).

b. The annual irrigation depletion (sprinkle irrigation from Table 3) includes 0.1 acre garden at 0.86 ac ft./ac, 0.2 acre lawn (turf) at 1.20 ac ft./acre and 0.13 acre (0.13 = 0.5 - .1 - .2 - 3,000/43,560) pasture at 1.29 ac ft./acre. This totals 0.49 ac ft. (0.49 = .1 x .86 + 2 x 1.20 + .13 x 1.29) for each lot and 9.9 ac ft. for all lots.

c. The proposed drain field site conditions are such that about 10% of the waste water will be additional depletion, the balance will be return flow. Thus, waste water depletion is 0.85 ac ft. [0.85 = 20 x 365 x 0.1 x (400-20)/325,850].

d. Total annual depletion is 11.2 ac ft. (11.2 = .45 + 9.9 + .85).

III.C. Domestic - Resort/Recreation

Depletions are estimated similar to those of Municipal - Culinary and Domestic - Subdivision except occupancy may not be year round in all units. Thus, the number of “equivalent annual household days” (EAHD) is determined and multiplied by 400 gallons per household per day to get the annual supply.

Example Domestic - Resort/Recreation

Example III.C.1. The application is for groundwater to supply a 130 lot Resort/Recreation development in Bear Lake County. Lot size is 1.5 acres with 0.1 acre irrigated. The anticipated waste water treatment is a composition of lagoons and septic system with drain fields. Estimated occupancy is:

Type	Units	Days Each
Permanent Homes (year long)	10%	365
Weekends during Oct-April	25%	61
Full Time May-Sep	40%	153
Weekends May-Sep	45%	44

The estimated EAHD is 17,258 days.
[17,258 = 130(0.1 x 365 + 0.25 x 61 + 0.4 x 153 + 45 x 44)]

a. Annual indoor depletion is 1.1 ac ft. (1.1 = 0.05 x 400 x 17,258/325,850).

b. The annual sprinkle irrigation depletion is estimated for 0.1 acre turf per lot at a unit depletion, from Table 1, of 1.25 ac ft./acre annually. The total development annual estimated irrigation depletion is 16.3 ac ft. (16.3 = 130 x 0.1 x 1.25).

c. It is estimated that 23% of the culinary waste water will be additional depletion, giving a waste water depletion of 4.9 ac ft. (4.9 = 0.23 x 400 x 17,258/325,850).

d. Total annual depletion is 22.3 ac ft. (22.3 = 1.1 + 16.3 + 4.9).

IV. Commercial/Industrial

Water supply amounts should be estimated from the IDWR recommendations (Table 8 in Appendix) if historical measured volumes are not available. Indoor depletion is five percent of corresponding supply for uses similar to municipal - culinary plus any irrigation depletion plus waste water depletion plus process water depletion and other depletion (if any.)

Example Commercial/Industrial

Example IV.1.

The application is for groundwater to supply an egg production industry comprised of 200,000 laying hens. There are three shifts daily averaging 16 employees each shift. The culinary (employee use) waste water is treated with 10% additional depletion. However, the poultry drinking and cleaning water is totally depleted.

a. There are 48 person-shifts each day. Assume that the culinary water use is equivalent to that of 24 persons in a residence situation. With an average of four occupants per residence, the culinary use is the same as six residential connections. The annual depletion is 0.13 ac ft. (0.13 = 6 x 365 x 0.05 x 400/325,850).

b. The culinary waste water depletion is 0.27 ac ft. (0.27 = 6 x 365 x 0.10 x 400/325,850).

c. The drinking water supply is given as 5-10 gallons per day per 100 chickens in Table 5. Assuming the high value applies to laying hens, the annual drinking water depletion is 22.4 ac ft. [22.4 = (200,000/100) x 365 x 10/325,850].

d. The quantity of cleaning water was not given, thus, assume it to be 10% of the chicken drinking water. The depletion is 2.2 ac ft. [2.2 = (200,000/100) x 365 x 1/325,850].

e. Total annual depletion is 25 ac ft. (25 = .13 + .27 + 22.4 + 2.2).

V. Miscellaneous - Ponds/Wetland Vegetation

Estimates of evaporation from shallow lakes and ponds and of consumptive use (or evapotranspiration, Et) for cattail wetlands of small (less than 1/4 acre) and large (20 acres or more) areal extent are given in Table 6. The Et values in Table 6 are based on the assumption that the surrounding area is irrigated land, particularly in the prevailing upwind (or fetch) direction. If the surrounding area is dryland (rainfed only) adjacent to the wetland vegetation, then an upward adjustment (adapted from Allen, 1995) varying from 109% to 132% should be made for large and small areas, respectively. A linear interpolation may be used for in-between surrounding conditions and areal extent and intermediate vegetation height. This adjustment should be applied to the Et value prior to subtracting effective precipitation for estimating depletion.

The open water surface evaporation values shown in Table 6 apply to shallow lakes with a water surface area of 40 acres or larger. These do not apply to a large deep lake such as Bear Lake.

Adjustments to open water evaporation for areas less than 40 acres should be made using the following factors:

Area, acres:	5	10	20	40

Adjustment Factor, Fea 1.23 1.15 1.07 1.00

Open water surface depletion adjusted for area is calculated as:

Open Water Depletion = Fea x Evaporation - Seasonal Precipitation (4)

where: Open Water Depletion is depletion from open water surface evaporation, inches; Fea is the evaporation area adjustment factor(after Lakshman, 1972); and Seasonal Precipitation is the total seasonal precipitation for the water year evaporation season (October plus April-September), inches.

Example Miscellaneous - Ponds/Wetland Vegetation

Example V.1. Estimate the annual depletion in Bear Lake County from a 10 acre cattail wetland downwind of dryland range.

Table 6. Estimated Water Year Depletion for Phreatophytes and Open Water Surface Evaporation in Bear Lake (Lifton, 1972-1996), Caribou (Grace, 1972-1996), and Franklin (Preston, 1976-1996) Counties

	Type	Water Use, Et Or Evaporation	Growing Season Precipitation	Depletion	
		in	in	inch	AF/ac
	Phreatophytes				
BEAR LAKE	Small Area	40.6	5.5	35.1	2.93
	Large Area	31.0	5.5	25.5	2.13
	Evaporation	28.0	7.6	20.4	1.70
	Phreatophytes				
CARIBOU	Small Area	42.1	6.9	35.2	2.93
	Large Area	32.0	6.9	25.1	2.09
	Evaporation	28.1	9.7	18.4	1.53
	Phreatophytes				
FRANKLIN	Small Area	47.0	7.3	39.8	3.31
	Large Area	35.7	7.3	28.5	2.37
	Evaporation	29.5	10.5	19.1	1.59

Growing Season precipitation is for May through September for phreatophytes and April-October for evaporation.

The estimated Et (interpolated for 10 acres from Table 6) is 35.7 inches (35.7 = (40.6 - 31.0) x (10 - .25)/(20 - 0.25) + 31.0]. The adjustment for dryland fetch is 1.2 [1.2 = (1.32 - 1.09) x (10 - .25)/(20 - .25) + 1.09].

Thus, the estimated depletion is 37.3 inches (37.3 = 1.2 x 35.7 - 5.5) or 31.1 ac ft. (31.1 = 10 x 37.3/12) for the 10 acre wetland which is situated in a dryland area.

Example V.2. The application is for two, five acre ponds to be used for fish propagation in Caribou County. The ponds are to be built close together in previously non-irrigated land downwind of irrigated pasture.

The depletion is estimated by adjusting the evaporation of 28.1 inches from Table 6 with an Fea of 1.15 (for 10 acres, there is no dryland adjustment) and then subtracting the precipitation. The annual depletion is 22.6 inches (22.6 = 1.15 x 28.1 - 9.7). This is equivalent to 18.8 ac ft. (18.8 = 10 x 22.6/12).

REFERENCES

Allen, R.G. 1995. Evapotranspiration from Wetlands, *Proceedings 1995 Seminar Evapotranspiration and Irrigation Efficiency,* sponsored by Am. Consult. Engr. Council of Colorado and Col. Div. Of W. Res. Arvada, CO. Oct 10-11.

Herbert, R.A. et al. 1990. Water Use, Chap 11 in *National Handbook of Recommended Methods for Water Data Acquisition,* USGS. U.S. Dept. Int., Reston, Va.

Hill, R.W. 1983. Alfalfa Yield and Water Use in Commercial Fields, *Proceedings ASCE Irrigation and Drainage Division Specialty Conference.* July 20-22. Jackson, WY.

Hill, R.W., C.E. Brockway, R.D. Burman, L.N. Allen, and C.W. Robison. 1989. *Duty of Water Under the Bear River Compact: Field Verification of Empirical Methods for Estimating Depletion*, Final Report, Utah Agricultural Experiment Station Research Report No. 125, Utah State University, Logan, UT. January.

Hill, R.W. 1994. *Consumptive Use of Irrigated Crops in Utah*, Utah Agricultural Experiment Station Research Report No. 145, Utah State University, Logan, UT, Oct.

Lakshman, G. 1972. *An Aerodynamic Formula to Compute Evaporation from Open Water Surfaces*, J. Hydrology. Vol 15:2 209-225.

________________. 1985. *Dairy Housing and Equipment Handbook.* MWPS-7, Iowa State University, Ames, IA. March

Wright, J.L. 1988. *Daily and Seasonal Evapotranspiration and Yield of Irrigated Alfalfa in Southern Idaho.* Agron. J. 80:662-669

APPENDIX

Agricultural Crop Depletion

The Amended Bear River Compact specifies (Articles V.C.; VI.B. and VI.C.) that depletions shall be determined by a Bear River Commission "Approved Procedure." These procedures are defined in "Amended Bear River Compact, Commission - Approved Procedures," November 1993. The depletion calculations are based on the procedure developed in the Bear River Commission funded research project "Duty of Water under the Bear River Compact: Field Verification of Empirical Methods for Estimating Depletions," (Hill, et al., 1989). In that report, agricultural depletion was calculated as the water year evapotranspiration less the sum of carryover soil moisture and effective precipitation. If the application were for supplemental crop water use, then a prorated depletion increase should be determined. For a crop such as alfalfa, the supplemental depletion factor could be derived as shown below.

Growing season precipitation was considered to be 80 percent effective in contributing to crop water use. The effectiveness factor of 80 percent includes a reduction for mismatches in timing between rainfall events and irrigation scheduling that might differ from National Weather Service reported rainfall.

The carry-over soil moisture (SM_{co}) was estimated by assuming that 67 percent of adjusted precipitation from October through April could be stored in the root zone. If this exceeded 75 percent of the available soil water-holding capacity of the crop root zone, the excess was considered as lost to drainage or runoff and not available for crop use. Adjusted precipitation was equal to total precipitation minus 1.25 times any calculated E_t occurring during October-April. This adjustment (1.25 E_t) for crop water use during the "non-growing" season was consistent with how effective precipitation was estimated in the growing season. The growing season was assumed to be May 1 through September 30. Thus, some E_t occurs outside this period (e.g. in April).

Sprinkle irrigation depletions are adjusted for wind drift loss with mild to moderate wind conditions. The evaporation loss from water droplets in the air with this adjustment is eight percent of delivered water in field crops and 10 percent for turf and gardens. Assuming 65% irrigation application efficiency for sprinklers the adjustment is a multiplier on surface irrigation depletion of 1.12 and 1.15 for eight percent and 10%, respectively.

Derivation of Supplemental Irrigation Depletion Factor

To determine a prorated depletion for Et increases from supplemental irrigation, a supplemental factor, Splf is defined as:

$$\text{Splf} = (\text{Et full} - \text{Et deficit})/\text{Et full} \qquad \text{(a)}$$

where Et full is crop water use (evapotranspiration) obtained with a full water supply and Et deficit is evapotranspiration under deficit or limited irrigation supply.

In a study of crop water use and alfalfa yields in farm fields in central Utah (Millard and Iron Counties) Hill (1983) derived the following relationship:

$$\text{Yield} = -0.765 + 0.243\ \text{ET} \qquad \text{(b)}$$

where yield is alfalfa yield, ton/acre, field dry (12 percent moisture) and ET is seasonal crop water use, inches. This is equivalent to 4.7 inches of ET per ton/acre at a yield level of 5.5 ton/acre. Wright (1988) suggests that it takes 5.0 inches of ET to produce one ton/acre alfalfa yield (Yield = 0.2 ET) for the range in yields observed in his southern Idaho lysimeter and field study. Either Equation (b) or Wright's relationship could be used to estimate Et for full and deficit conditions of Eq. (a).

As an example, using Eq. (b), if deficit condition yields are four ton/acre and full supply yields are seven ton/acre then Et full would be 32 inches (32 = (7 + 0.765)/0.243) and Et deficit would be 19.6 inches (19.6 = 4 + 0.765)/0.243) by solving Eq (a) above for Et. Thus, the supplemental factor becomes: Splf = (32 - 19.6)/32 = 0.39.

Depletion for A Typical 100 Lactating Cow Dairy

Dairy supply requirements (adapted to Cache Valley conditions from MWPS-7, 1985) and depletion estimates were developed for an assumed "typical" dairy herd with an average of 100 lactating cows plus associated dry cows (22), replacement heifers (74, 6-15 month old) and young heifer calves (37, newborn to six months) and slurry manure handling operation and land application. The estimated monthly supply and depletion values of such a dairy herd are given in Table 7. The supply requirements vary from 130,000 gallons in January to 214,200 gallons in July and total about 75 acre-inches volume annually. This is equivalent to 0.027 ac-ft per animal per year (0.027 = 75.1/(12 x 233)), or about 24 gallons per day per animal (24 = 2,040,350/(233 x 365)). The average of 35 gallons/cow per day for the lactating cows (see Table 7) agrees with the Idaho Department of Water Resources (IDWR) daily value of 35 gallons/head. However, this becomes 43 gallons/head per day when eight gallons are added for wash water. The 133 animals in the balance of the herd average about 10 gallons/head per day.

The current concern about water quality has led to regulatory agency policy insisting on no surface runoff of animal wastes and moving toward a policy of zero deep percolation into ground water. The implementation of such policy will bring about 100 percent depletion of dairy supply water.

Assuming 90 percent depletion of wash and rinse water and animal waste water (and 100% depletion of water in milk), the estimated annual total depletion is 68.6 acre-inches for the 233 animals associated with a 100 lactating cow dairy herd (as shown in Table 7). This is equivalent to 0.025 ac-ft per animal per year. The depletion of culinary water for a 100 lactating cows dairy operation is at least the 68.6 acre inches (for a 100 cow milking herd) and in the foreseeable future may become all of the supply, or 75.1 acre-inches per year.

Depletion for Municipal and Domestic

Estimates of non-irrigation, indoor, depletion of domestic culinary water vary from two to ten percent of water supply, although some "losses" may be as high as 30 percent. The culinary (non-irrigation) depletion could be as high as 100 percent in total containment, lagoon type waste water disposal systems placed on previously non irrigated land.

The major source of depletion of culinary water use is irrigation of lawns, gardens, trees and ornamentals during the summer months. This is related to evapotranspiration (ET) rates (such as in Hill, 1994) and irrigation method. The estimated municipal irrigation depletion is equal to the irrigated area multiplied by the depletion given for turf and/or gardens in Tables 1-3.

The actual area irrigated in a given community in the Bear River Basin from the culinary water supply depends on what other water supply may be available for irrigation and may vary from spring to summer. In the springtime and early summer, when flow from streams and springs is high, culinary water may be used for irrigation on a smaller area than later in July as stream flow is diminished and residents wish to maintain lawns and gardens. This trend toward watering more area with culinary supplies may also be more pronounced in droughts.

Simplified Municipal and Domestic Depletion Calculation using "Standardized Lots"

The examples in section III include details to illustrate the calculations. A simplification based on "standardized lots" for municipal depletion calculations is possible using Tables 9, 10 and 11. Table 9 contains the land use category assigned to "typical" lots varying in area from 0.25 to 5.00 acres. For example, a 0.5 acre "standardized lot" lot consists of 0.12 acre house footprint, 0.30 acre lawn and 0.08 acre garden. As the lot sizes increase, pasture and alfalfa hay are added.

The annual indoor depletion for an average household (0.04 ac-ft) along with the sprinkler irrigation depletion for lawn (turf), garden, pasture, and alfalfa hay from Tables 1, 2, and 3 are given by county in Table 10 for convenience. The estimated total annual depletion (indoor plus irrigation) by lot size and county is given in Table 11. The values in Table 11 are the sum of the indoor depletion from Table 10, plus the product of the respective crop category area in Table 9 with the corresponding depletion in Table 10.

The use of "standardized lots" to estimate municipal culinary and irrigation depletion is similar to Example III.A.1, page 7. That example was for a Franklin County community with 150 residences and an average lot size of 0.33 acre. The corresponding annual "simplified" depletion is 45 ac-ft (45 = 150 x 0.30) where the 0.30 unit depletion value came from Table 11 for a 0.33 acre lot in Franklin County. This value is about 6% lower than the corresponding Example III.A.1 depletion of 47.5 ac-ft (47.5 = 3.4 + 44.1), excluding the waste water system depletion.

Table 7. Estimation of Monthly Distribution of Dairy Cow Water Requirements and Depletion using Monthly Average Temperature from Preston, Idaho(1975-1996) as the Basis for Prorating Drinking Water During the Year, and Assuming Slurry Manure Handling with 10% Return Flow

				100 Cow Herd Supply			100 Cow Herd Depletion			Total Depletion	
Month	Days in Month	Average Temp-F	1400 Lb Cow Gal/Day	Herd Total Gal/Day	Month Total Gal	Total Ac-in	Milk Export Water Gal/Day	Culinary Water Depletion Gal/Day	Total Gal/Day	Gallons	Ac-in
Jan	31	19.5	25	4195	130037	4.79	690	3154	3884	119173	4.39
Feb	28	25.0	27	4498	125948	4.64	690	3427	4117	115285	4.25
Mar	31	35.9	32	5090	157796	5.81	690	3960	4650	144155	5.31
Apr	30	45.4	35	5607	168225	6.20	690	4426	5116	153472	5.65
May	31	53.2	39	6035	187077	6.89	690	4810	5500	170509	6.28
Jun	30	61.8	42	6506	195170	7.19	690	5234	5924	177723	6.55
Jul	31	69.2	45	6911	214227	7.89	690	5598	6288	194943	7.18
Aug	31	67.7	44	6827	211622	7.79	690	5523	6213	192599	7.09
Sep	30	58.7	41	6335	190062	7.00	690	5081	5771	173126	6.38
Oct	31	46.9	36	5689	176370	6.50	690	4499	5189	160872	5.92
Nov	30	32.9	30	4928	147844	5.44	690	3814	4504	135130	4.98
Dec	31	23.0	26	4386	135975	5.01	690	3327	4017	124516	4.59
Total	365				2040353	75.14				1861502	68.56
Aver		44.9	35	5584					5175		

Note: Estimates for a typical 100 cow milking herd are based on: a) 100 milking cows (ave wt 1400 lbs) producing 19,000 lbs of milk per lactation, each drinking 25 to 45 gallons of water/day (lower in winter and higher in summer) plus 8 gallons of wash water/day, b) 22 dry cows (ave wt 1400 lbs) each drinking one half of value for milk cows (no wash water), c) 74 replacement heifers (ave wt abt 800 lbs) each drinking about 57% as much as dry cows; age from 6 months to first calving at about 15 months, d) 37 young heifers (ave wt abt 130 lbs) each drinking about 20% as much as dry cows; age from newborn to 6 months

There are 233 animals total for a 100 cow milking herd. Thus the average annual water use per animal is 24 gallons per day (24=2,040,353/(233x365))

Depletion calculated as the total of water in exported milk plus 90% of remaining culinary supply.

Table 8. Average Daily Water Supply Requirements for Other Uses (from Appendix IV, Idaho Water Law Handbook, IDWR)

OTHER USES	Gallons Per Day
Camps:	
Construction, semipermanent (per worker)	50
Day, with no meals served (per camper)	15
Luxury (per camper)	100-150
Resorts, day and night, with limited plumbing (per camper)	50
Tourist with central bath and toilet facilities (per person)	35
Picnic grounds:	
With bathhouses, showers and flush toilets (per person)	20
With toilet facilities only	10
Parks:	
Overnight with flush toilets (per camper)	25
Trailers with individual bath units, no sewer connections (per trailer)	25
Trailers with individual bath units, connected to sewer (per person)	50
Highway rest area (per person)	5
Hotel - with private bath (two persons per room)	60
without private bath (per person)	50
Motel - with bath and kitchenette (per bed space)	50
with bath (per bed)	40
Boardinghouse (per resident)	50
- additional use for nonresident boarders (per person)	10
Rooming house (per resident)	60
Restaurants: With toilet facilities (per person)	7-10
Without toilet facilities (per person)	2 ½ - 3
With bar/lounge (additional quantity per patron)	2
Schools:	
Boarding (per student)	75-100
Day with cafeteria, gym and showers (per student)	25
Day with cafeteria, without gym and showers (per student)	20
Day without cafeteria, gym or showers (per student)	15
Hospitals (per bed)	250-400
Other Institutions (per person)	75-125
Airports (per passenger)	3-5
Churches (per person)	5
Laundries, self-service (per customer)	50
Service Stations (per vehicle)	10
Stores (per restroom	400
Swimming pools (per swimmer)	10
Theaters - drive in (per car space)	5
- movie (per seat)	5

Note: A more complete listing of industrial and other water supply values are given by Herbert, 1990.

Table 9. Distribution of Land Use Type for Various Sized Lots

Lot size, acre	House	Lawn	Garden	Pasture	Hay
	.... Category	....			
0.25	0.08	0.14	0.03		
0.33	0.10	0.18	0.05		
0.50	0.12	0.30	0.08		
0.75	0.14	0.30	0.08	0.23	
1.00	0.16	0.30	0.08	0.46	
1.25	0.18	0.30	0.10	0.67	
2.50	0.20	0.30	0.10	1.00	0.90
5.00	0.20	0.30	0.10	2.00	2.40

Table 10. Depletion Categories and Amounts for Bear Lake, Caribou, and Franklin Counties, Idaho

County	Indoor	Lawn	Garden	Pasture	Alfalfa
	.... Annual Depletion				
	ac-ft	. . . . ac-ft/ac			
Bear Lake	0.04	1.25	0.85	1.33	1.74
Caribou	0.04	1.11	0.71	1.23	1.59
Franklin	0.04	1.20	0.86	1.29	1.65

Table 11. Estimated Total Indoor plus Irrigation Depletion for Various Sized Lots, by County

Lot size,acre	Bear Lake	Caribou	Franklin
	. . . . Annual Depletion, ac-ft		
0.25	0.24	0.22	0.23
0.33	0.31	0.28	0.30
0.50	0.48	0.43	0.47
0.75	0.79	0.71	0.77
1.00	1.09	1.00	1.06
1.25	1.39	1.27	1.35
2.50	3.40	3.11	3.26
5.00	7.34	6.72	7.03